

Space Weather Technical Forecast

Issued on Monday 30 December 2024 at 01:06 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>

Space Weather Forecast Headline: R1/R2 Radio Blackouts expected throughout. Chance of R3 blackouts. A CME arrival is expected on 31 Dec, with G1-G2 Minor/Moderate storm likely, with a slight chance of G3 Strong storm.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity at GOES16 has been High, with a X1.1 flare observed from AR3936 at 29/0718 UTC. Much of the remainder of the activity appears to have emanated from AR3932 and AR3929 in the western quadrant and from AR3939 in the southeast. There has also been evidence of some flaring from beyond the eastern limb.

There are currently ten sunspot regions on the visible disc. AR3936 is the largest and most active region in the northwest quadrant, but has been relatively stable in terms of growth over the last 24 hours. AR3939 is growing in size but still exhibits a beta configuration. AR3938 also appears to be stable, but the magnetic configuration is also appearing to simplify. AR3932 is fading rapidly with many of the spots weakening markedly. AR3941 is also developing albeit slowly, with no significant spots emerging. The regions close to the western limb are difficult to diagnose. The remaining regions are all simple or only slowly evolving.

Numerous CMEs have been observed leaving the disc on SOHO LASCO imagery over the past 24 hours. However, these mostly considered to have been far-sided in origin. A filament eruption and dimming event was observed on GONG H-alpha imagery in the vicinity of AR3939 at 29/0436 UTC, which produced a partial halo CME seen in LASCO and STEREO-A imagery. This event has been analysed and the results show an Earth-directed CME, which is expected to arrive at Earth on Day 2 (31 Dec).

Another partial halo has recently emerged in LASCO imagery after 29/1800UTC, although it appears to be more faint compared to the previous event. This is currently undergoing analysis to determine if any further Earth-directed component.

Solar Wind / Geomagnetic Activity: Solar winds, as observed at L1 by ACE and DSCOVR remained mostly at background levels throughout, but increased briefly to slightly elevated levels, peaking just above 400km/s, between 29/1630-1900UTC. Density was mostly below average to average. The Interplanetary Magnetic Field (IMF) was weak through much of the period, but reached moderate levels intermittently from 29/0600 UTC. The north-south component remained weak but erratic, ranging between -6nT and +8nT. Phi angle was mostly negative (towards the

Sun). The net result of the above solar wind measures was Quiet geomagnetic activity throughout (Kp 0-2).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) at GOES18 remained at background throughout, well below the S1/Minor Radiation Storm threshold.

High energy electron flux (greater than 2MeV) at GOES16 was at Moderate levels, peaking at 29/1500 UTC at 307pfu. The associated 24-hour fluence was below the Active ($1e8$ integrated flux) threshold on a slightly declining trend. The 30/0001UTC observation was $6.97e6$ integrated pfu.

Four-Day Space Weather Forecast Summary

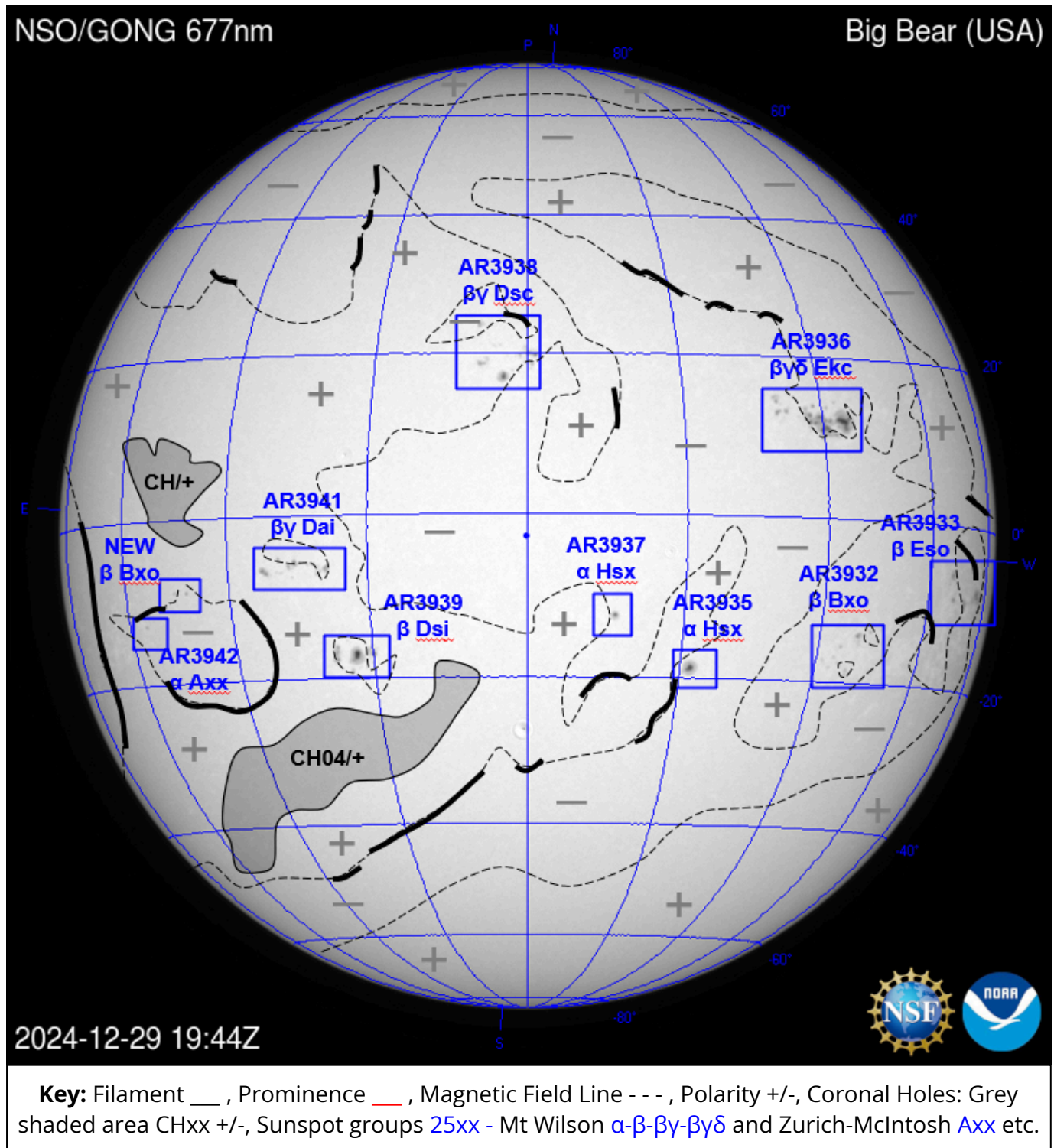
Solar Activity: Generally Moderate solar activity is expected through the next four days, with an elevated risk of High activity, especially from AR3936 in the northwest quadrant. There is an increasing risk of activity from regions due to rotate onto the visible disc from the far-side of the Sun.

Solar Wind / Geomagnetic Activity: No coronal hole fast winds currently feature in the forecast. A partial halo CME observed in SOHO LASCO C2/C3 looks to be associated with an M2.0 flare and a filament eruption near the vicinity of AR3939 in the southeast quadrant at around 29/0440UTC as observed in GOES SUVI imagery. A dimming associated with this event was seen in GOES SUVI 195 imagery. This event has been analysed, with an Earth-directed CME expected to arrive on day 2 (31 Dec), although further analysis is currently underway.

Geomagnetic activity is expected to be mainly Quiet, but with a Slight Chance of Unsettled to Active (Kp 3-4) intervals should any glancing CME effects occur between 30 Dec to 01 Jan. The aforementioned Earth-directed CME arriving on Day 2 (31 Dec) is expected to enhance geomagnetic activity, reaching G1-G2 Minor/Moderate storm, with a slight chance of G3/Strong storm. The effects of the CME may linger into Day 3 (01 Jan), before waning by Day 4 (02 Jan).

Energetic Particles / Solar Radiation: There is a Slight Chance of S1/Minor Radiation Storm or greater enhancements during the period, this risk slightly increases later in the period as the larger groups rotate into a more favourable position. Electron flux levels remain Moderate but are expected to gradually ease into the period in the absence of any enhancement.

Figure 1: Solar Map Analysis - valid 29/1944 UTC.



Geomagnetic Storms

A filament lift-off (following an M2 flare) from the southeast quadrant, close to AR3939 around 29/0436 UTC appears to have produced a fast partial halo CME, which has been analysed as Earth-directed, with an expected arrival on the 31 Dec (estimated time of arrival 1500 UTC). A number of CMEs are currently modelled in Enlil on the Sun-Earth line with a potential for a series of low confidence passages from 30 Dec to 02 Jan.

Solar winds are otherwise are averaging around 350km/s and are expected to remain at background levels, before the arrival of the aforementioned CME on the 31 Dec, where solar winds could reach strong levels, above 600km/s.

Geomagnetic activity is forecast to be mostly Quiet on Day 1 (30 Dec). The arrival of the anticipated partial halo CME, which left the Sun on the 29 Dec, is Likely to enhance geomagnetic activity to G1-G2/Minor-Moderate storm levels, with potentially a Slight Chance of reaching a G3/Strong storm interval on Day 2 (31 Dec). Any CME effects persisting into Day 3 (01 Jan), before gradually waning by Day 4 (02 Jan) back towards Quiet to Unsettled conditions, with isolated Active intervals.

Geomagnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	5	60	30	5
Strong	G3	No	1	20	10	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R _☉ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
2024-12-29 (0955UTC)	Partial	Near AR3939	Southeast	1015km/s	2024-12-31 (1500UTC)	M2 flare and associated filament eruption near AR3939 produced a partial halo CME.

Figure 2: SOHO LASCO C3 difference imagery, showing the partial halo CME, which has been analysed as Earth-directed, arriving on Dec 31.

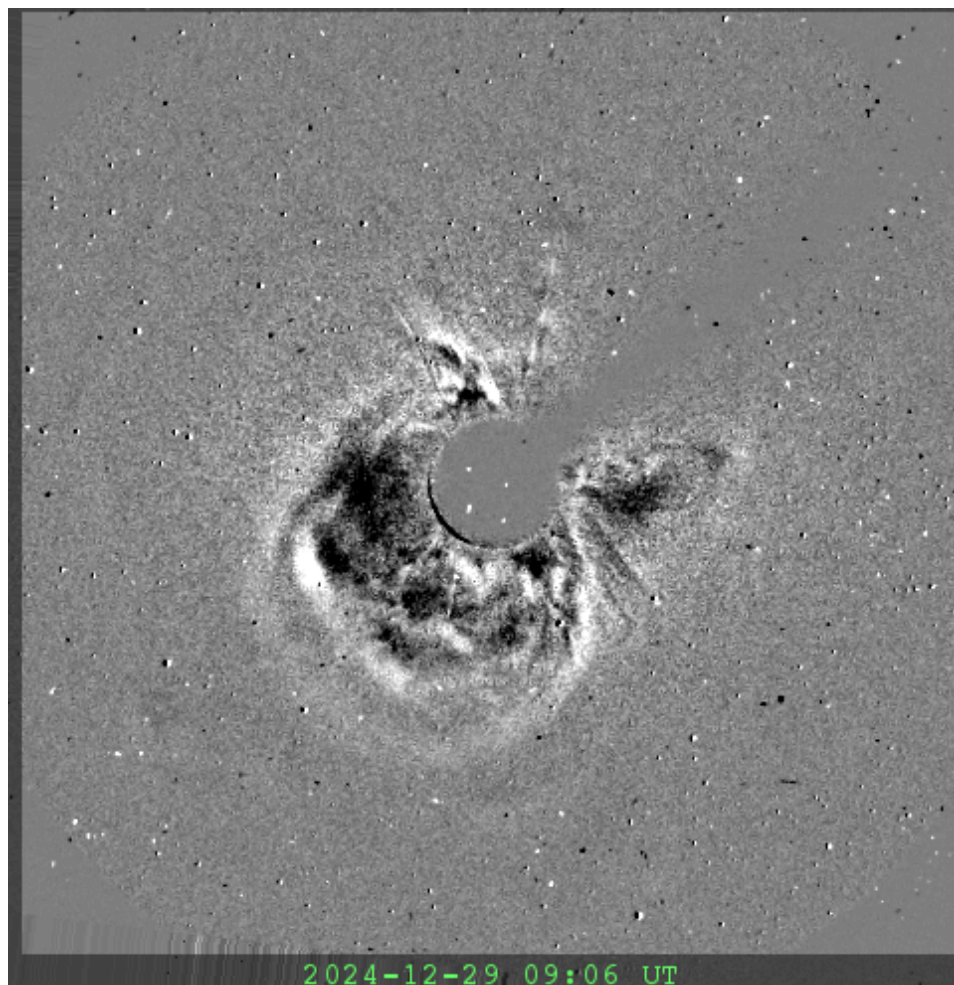


Figure 3: MOSWOC Enlil shows estimated arrival of the CME on 31 Dec.

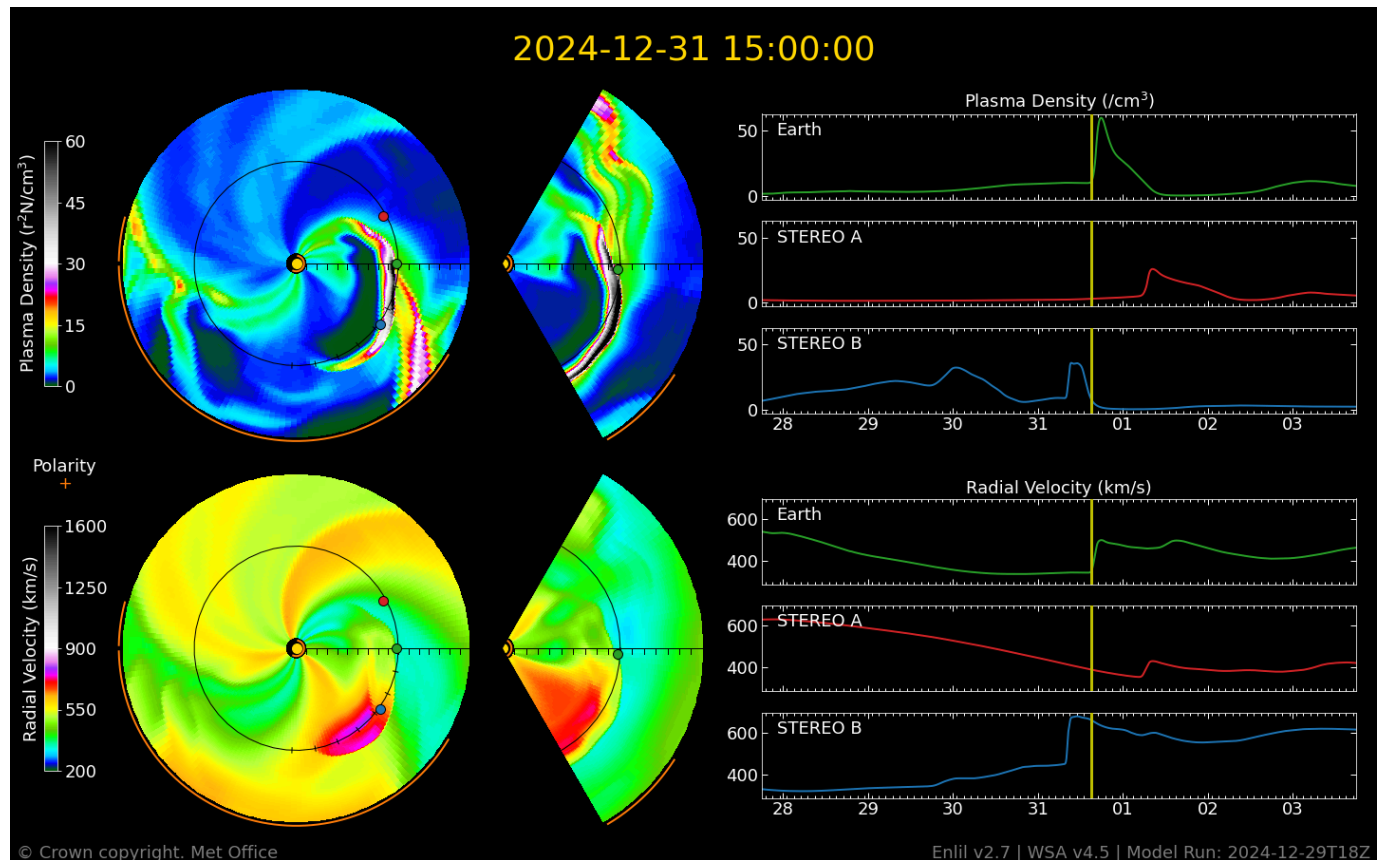
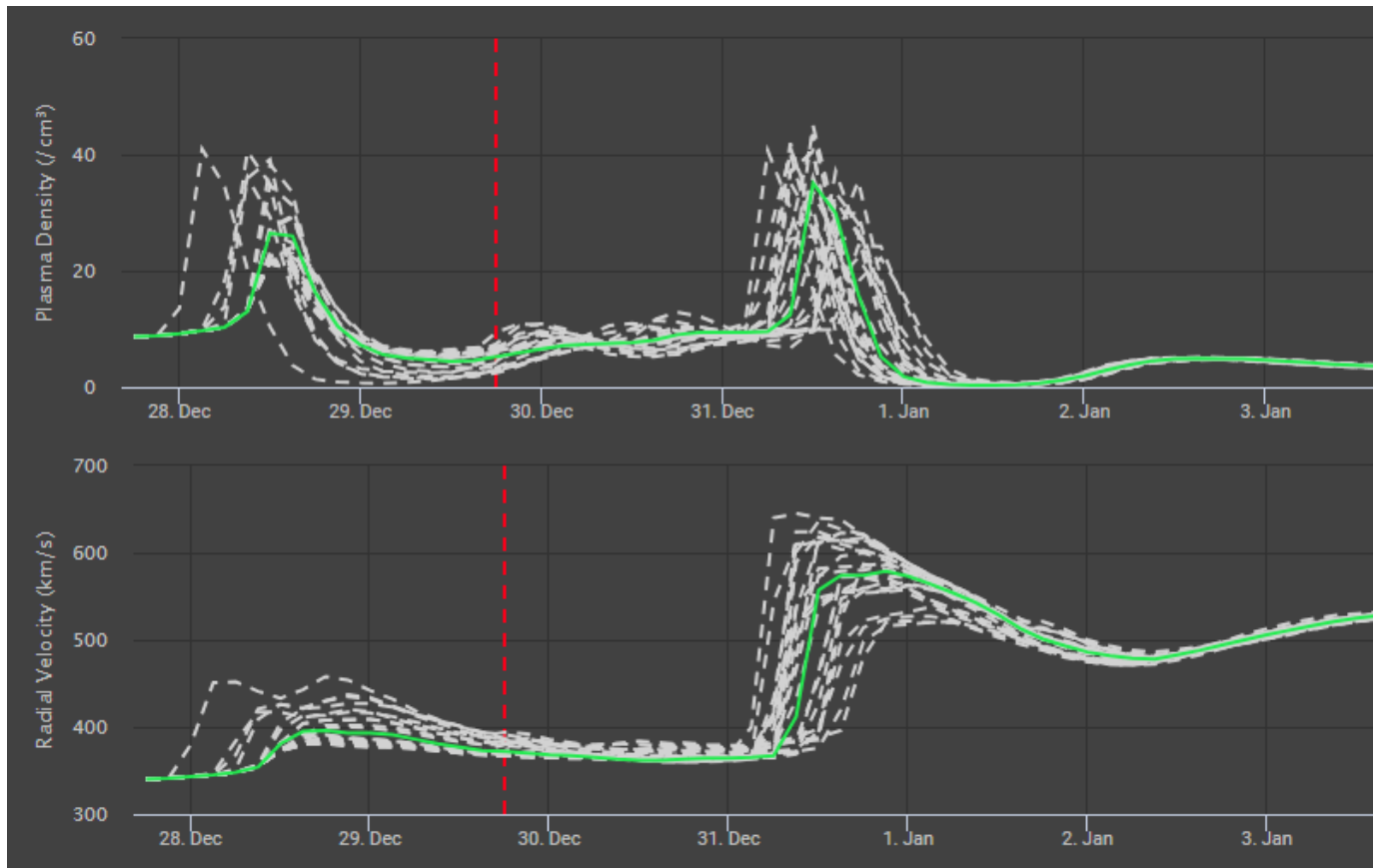


Figure 4: MOSWOC Enlil ensemble shows likely CME arrival times on the 31 Dec, with solar winds probably reaching in excess of 600km/s.



Radio Blackouts - X-Ray Flares

There are currently ten sunspot regions on the visible disc. There was an X1.1 flare early on 29 Dec from AR3936, which a large and complex feature in the northwest quadrant. This region consists of a beta-gamma-delta configuration. Recent activity near the vicinity of AR3939 in the southeast associated with an M2.0 flare at 29/0436 UTC and a subsequent filament eruption, which produced a partial halo CME. This event has been analysed as Earth-directed, with the CME expected to arrived at Earth on 31 Dec.

Recurrence suggests the potential for further sunspot regions to round the eastern limb during the period, with this supported by recent far-side CME activity. Although far-side sounding output is not showing any significant regions (likely due to their proximity to the limb where soundings have a minimum ability to detect such regions) limb flux looping and coronagraph imagery suggests the presence of regions approaching the limb. None of the four sunspot regions of note are expected to rotate off of the disc during the forecast period, although AR3933 and AR3928 will lie close to the western limb.

Flare risk is expected to be Moderate through the period, with an elevated risk of X-class flares, especially from AR3936 and from regions due to rotate onto the visible disc across the eastern limb.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	90	90	90	90
Very Active	R3-R5 (X Class)	Yes	30	30	30	30

Figure 5: GOES16-18 X-Ray Flux trace - shows multiple M-class flares in the past 24 hours, with an X1.1 flare observed at 29/0718 UTC.



Solar Radiation Storms (High Energy Protons)

High energy proton counts remain at background values, with neither the X1.1 flare from AR3936 or the filament eruption from the southeast quadrant resulting in a noticeable increase in proton counts. There remains a Slight Chance of S1/Minor Solar Radiation storms (or greater) should any significant flares occur from the larger regions on the disc as they rotate into more favourable locations for connection with Earth.

Radiation Storms	Level (cm ⁻² sr ⁻¹ s ⁻¹)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ S1	No	15	15	15	15
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = cm ⁻² sr ⁻¹ s ⁻¹)						

High Energy Electrons (≥ 2MeV)

High energy electron flux has remained at Moderate levels in the last 24 hours. A steady state diurnal oscillation is expected through the period with a slightly declining trend towards background. With no further drivers to increase electron populations, fluence will now most likely remain below Active throughout. MOSWOC REFM is now showing a steady forecast through the next three days, which is considered good guidance.

GEO Electron Environment	Level (cm ⁻² sr ⁻¹ day ⁻¹)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10 ⁸	No	5	5	5	5
Very Active	≥ 2 MeV ≥ 1×10 ⁹	No	1	1	1	1

Figure 6: GOES18 Electron Flux for the past 3-days.

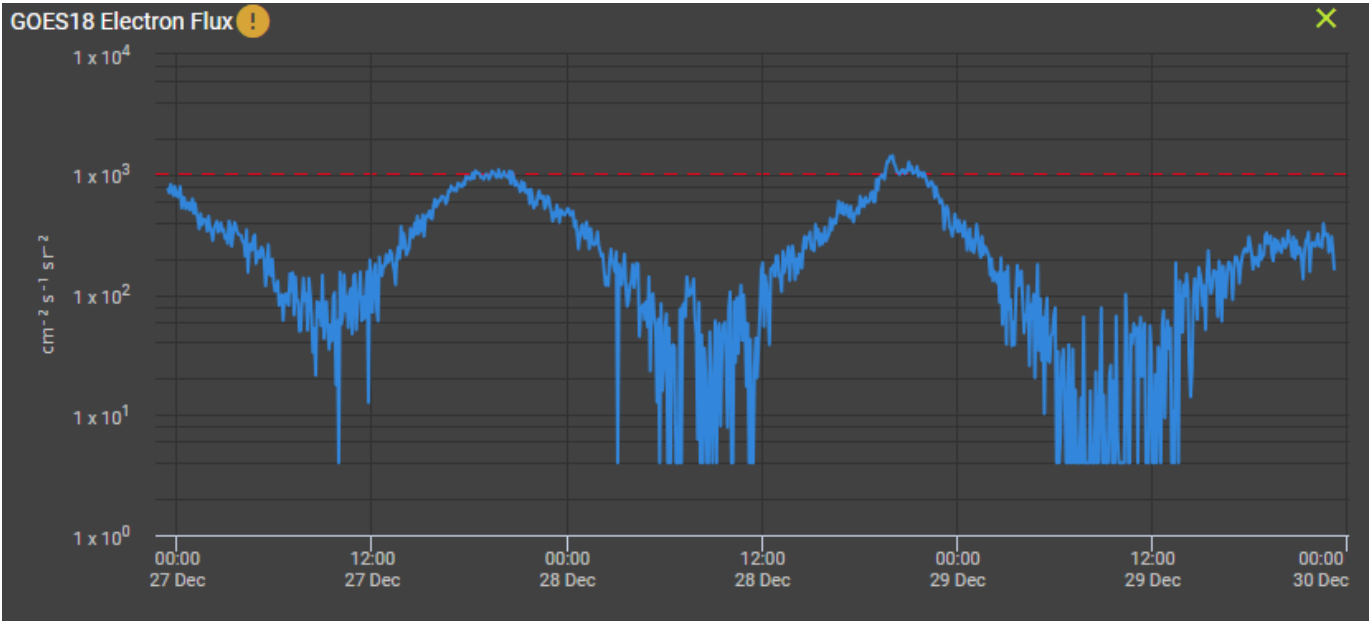


Figure 7: MOSWOC REFM electron fluence

